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Title: Flow Simulation Using Discrete Fracture Network Model

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Flow Simulation Using Discrete Fracture Network Model

Preliminary Results

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August 28, 2018



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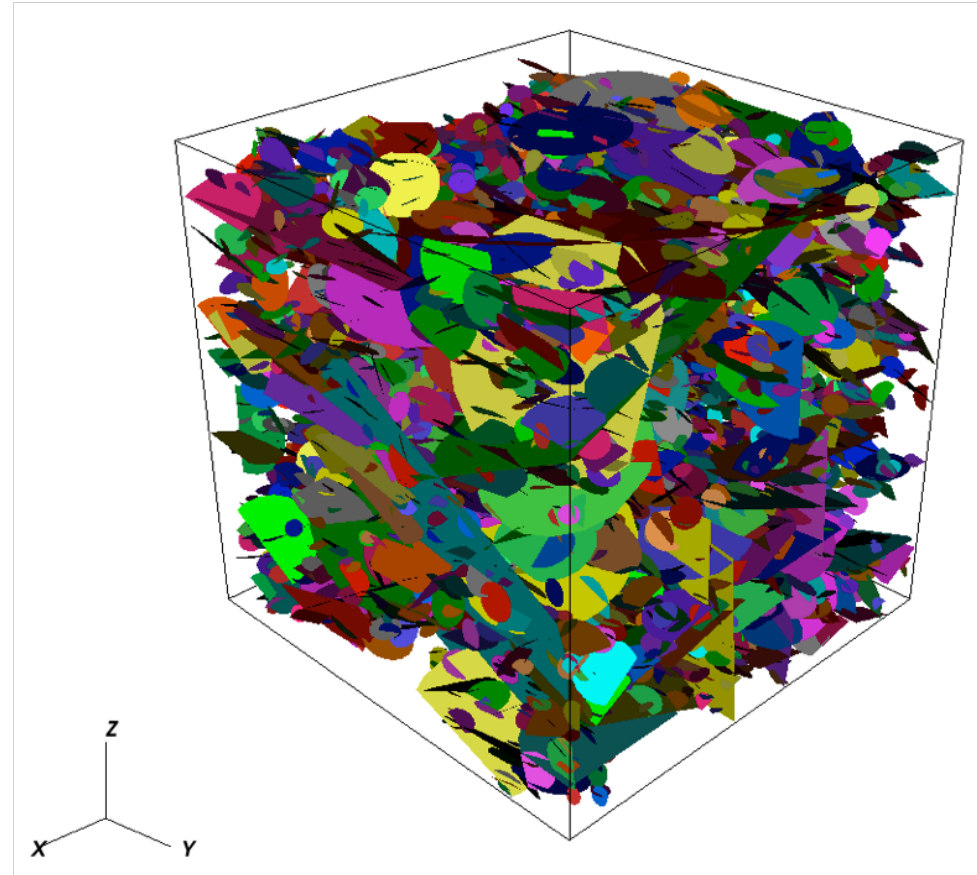
- ***dfnGen***
 - Network Generation using **FRAM**
- ***dfnFlow***
 - Flow simulation using **PFLOTRAN**
- ***dfnTrans***
 - Lagrangian Particle Tracking

dfnWorks

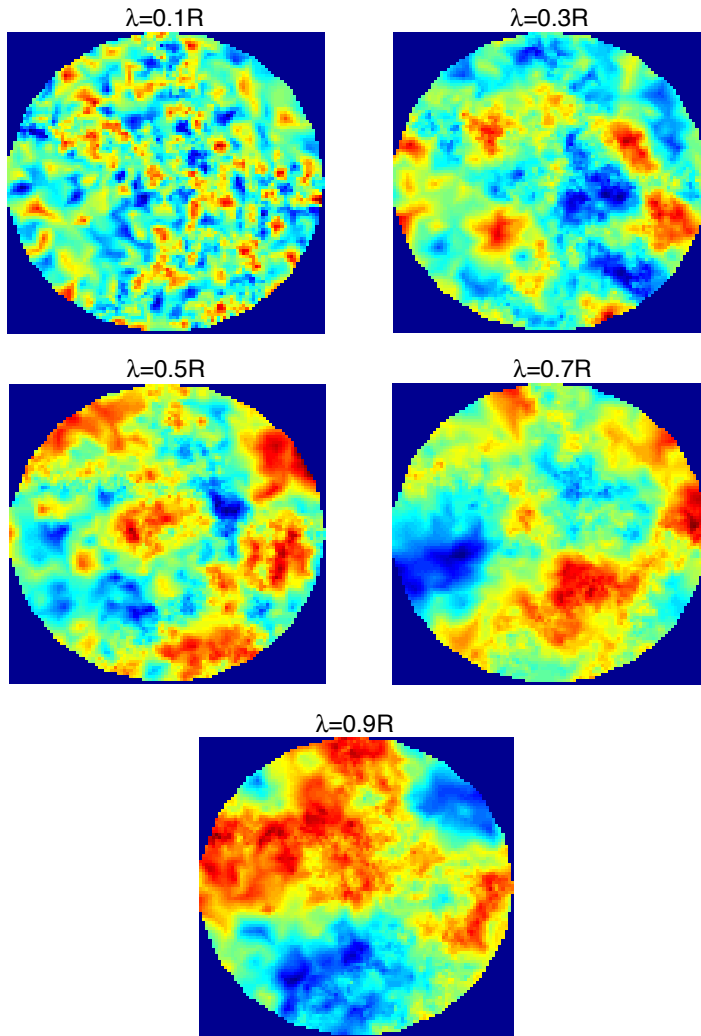
Stochastic Fracture Generation

Each fracture is assigned:

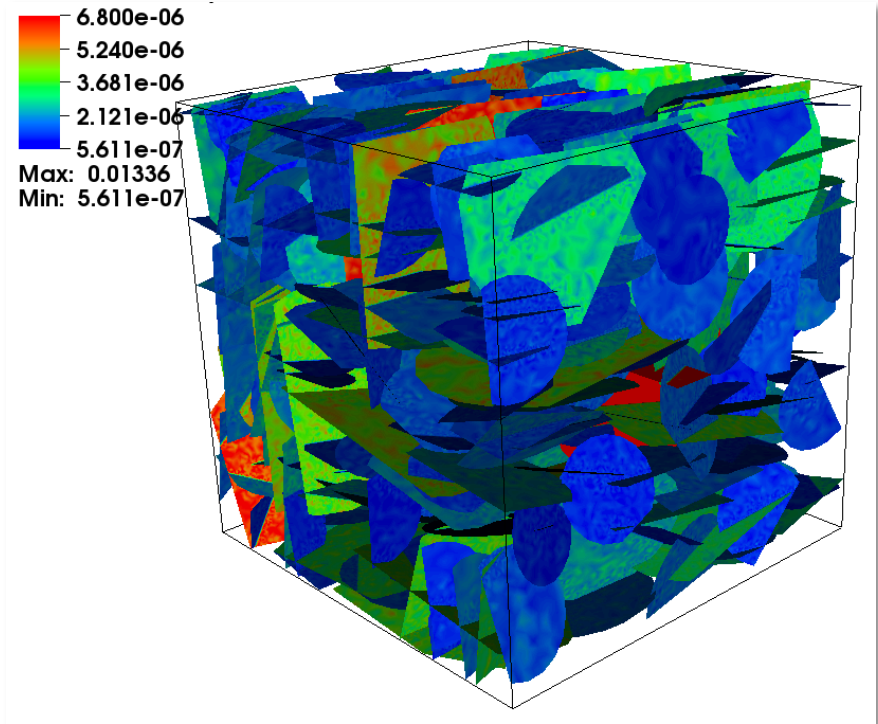
- **Shape**
ellipse, circle, square, rectangles
- **Size**
Power Law Distribution
Exponential Distribution
Log Normal Distribution
Constant
- **Location**
random
- **Aperture**
as function of fracture size
as function of given transmissivity
- **Orientation**
Fisher Distribution



Capability to apply internal heterogeneity of fracture aperture and transmissivity



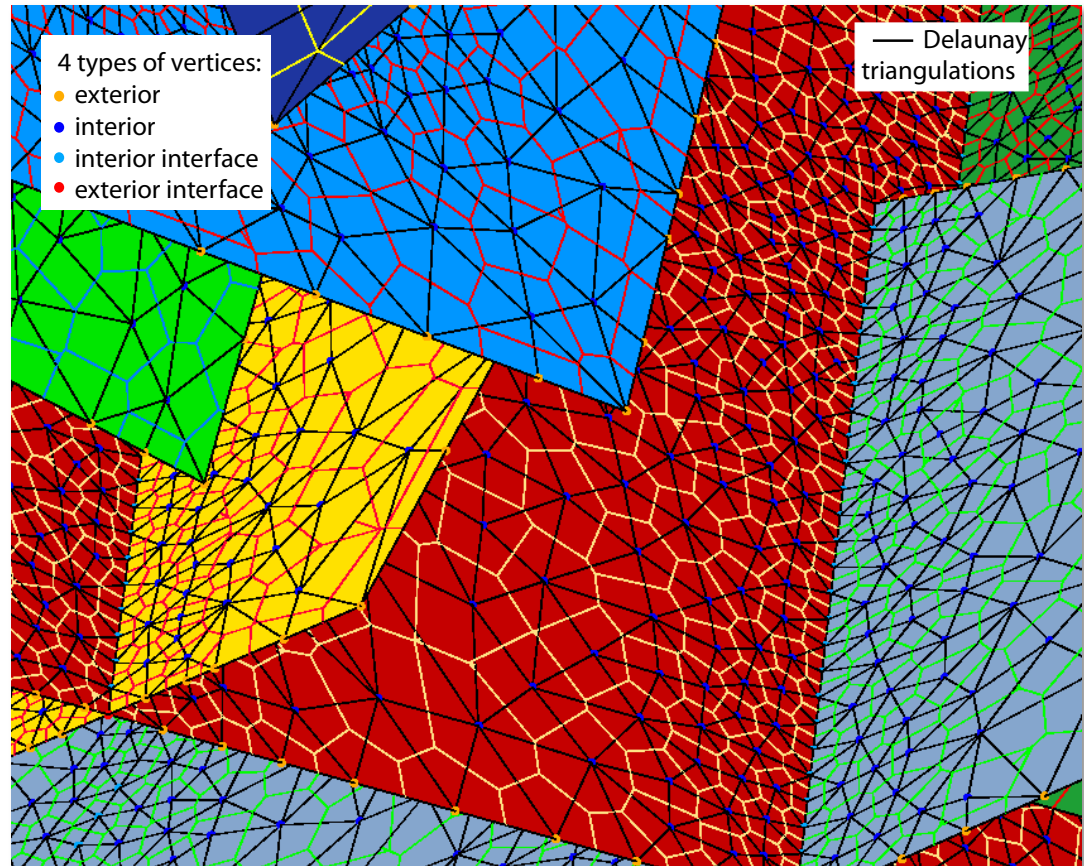
Transmissivity, m^2/s



λ – correlation length
 R – radius of circular fracture

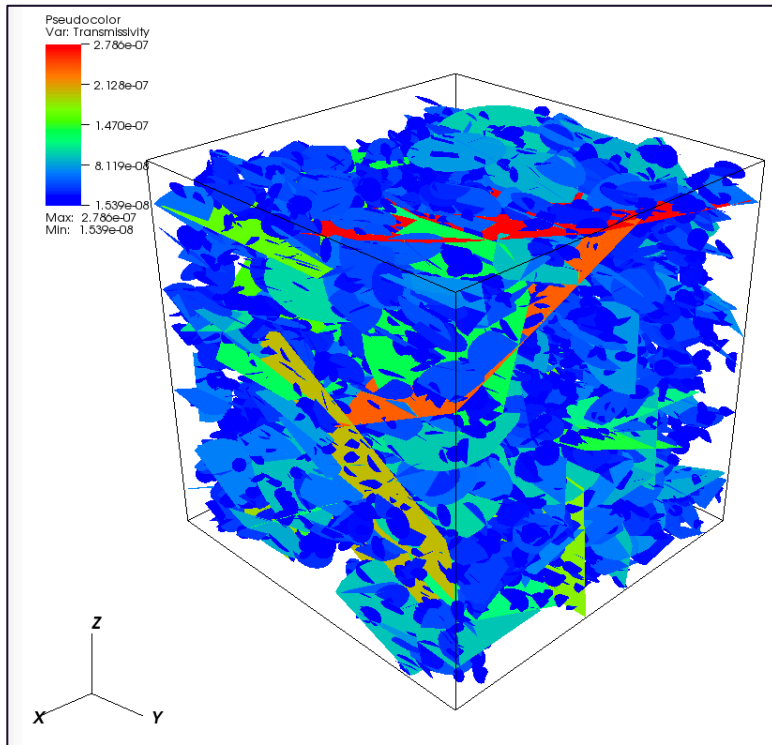
High-Quality Computational Mesh

- Automated Delaunay triangulation is performed
- Mesh cells are fine near intersections and coarse far from intersections
- The meshes for each of two intersecting fractures coincide along the intersection
- Control volumes at intersections are 3D objects constructed from the union of planar Voronoi cells.

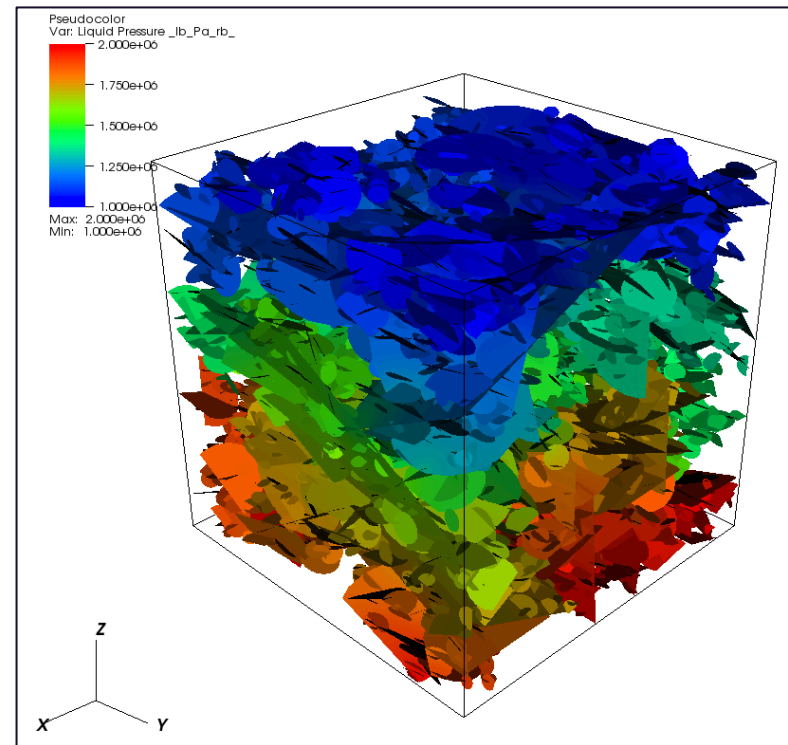


Steady State Flow Solution / PFLOTTRAN

Transmissivity profile [m^2/s]



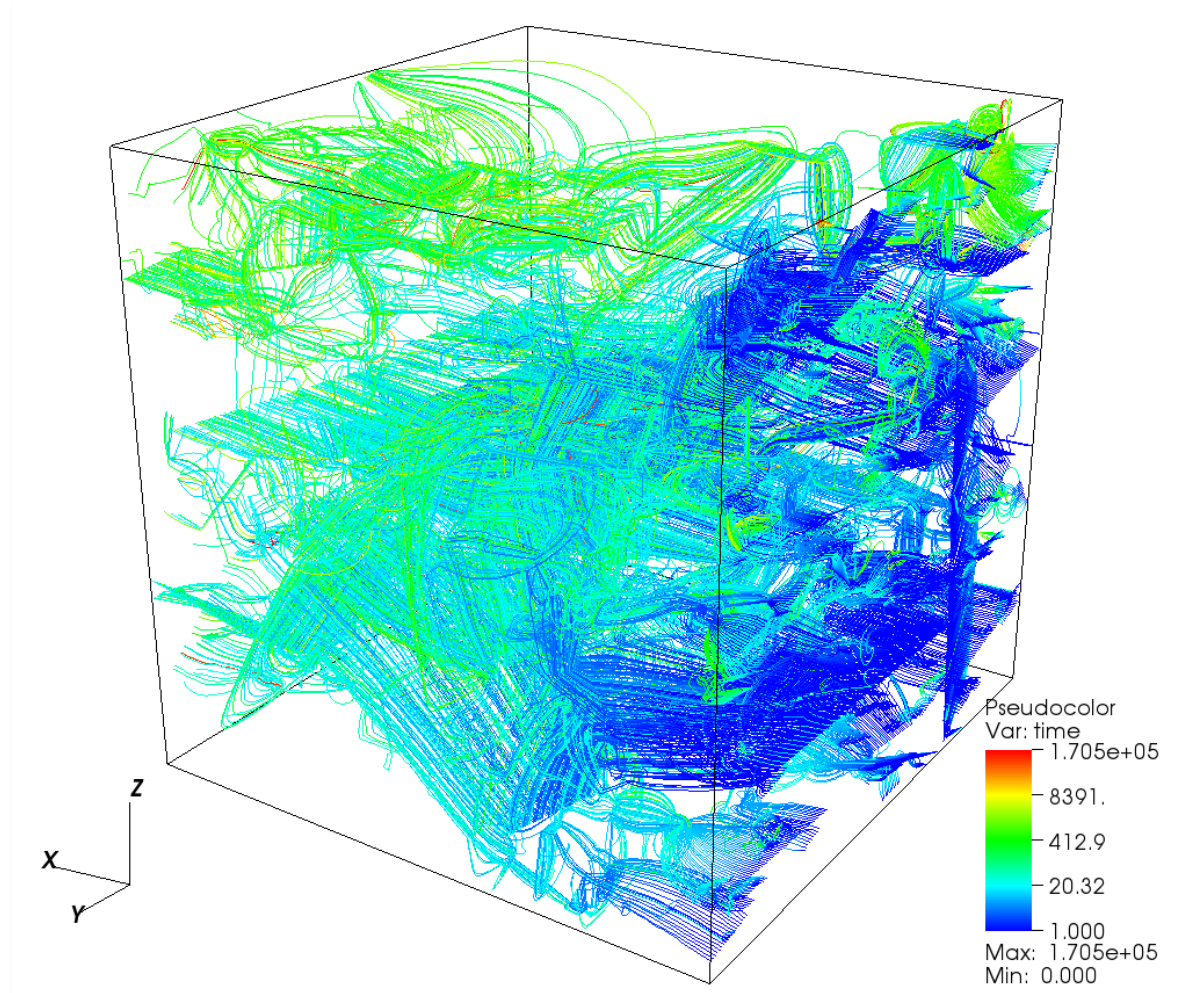
Pressure field [Pa]
Fluid flows from top to bottom



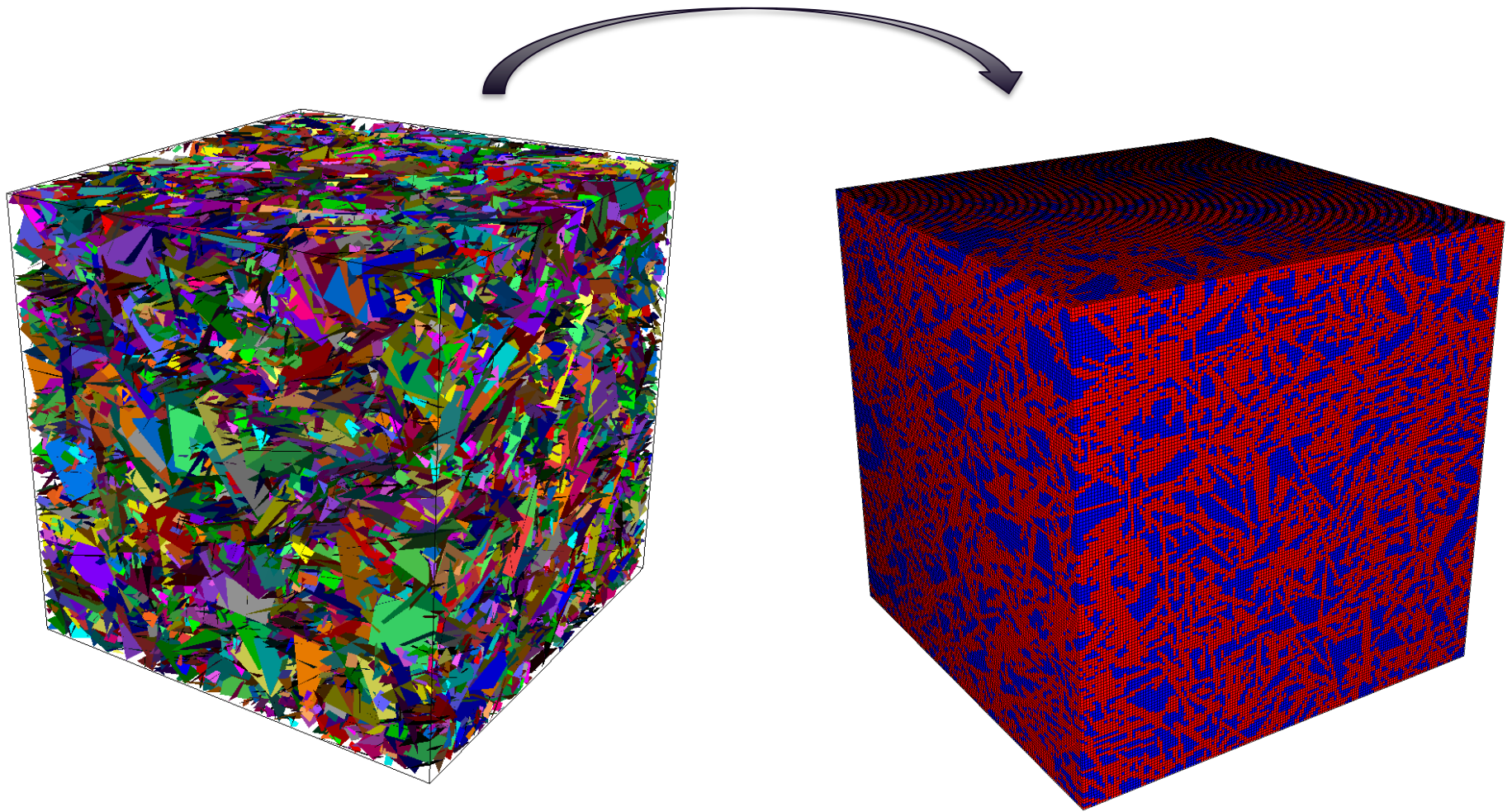
pflotran.org

Particle Tracking

- Darcy velocities are reconstructed at each node of computational mesh
- Every intersection node represents four velocity vectors, explicitly representing direction of flow on fracture intersections
- Tracking particles in flow field through three-dimensional fracture network



Mapping of DFN into a Continuum

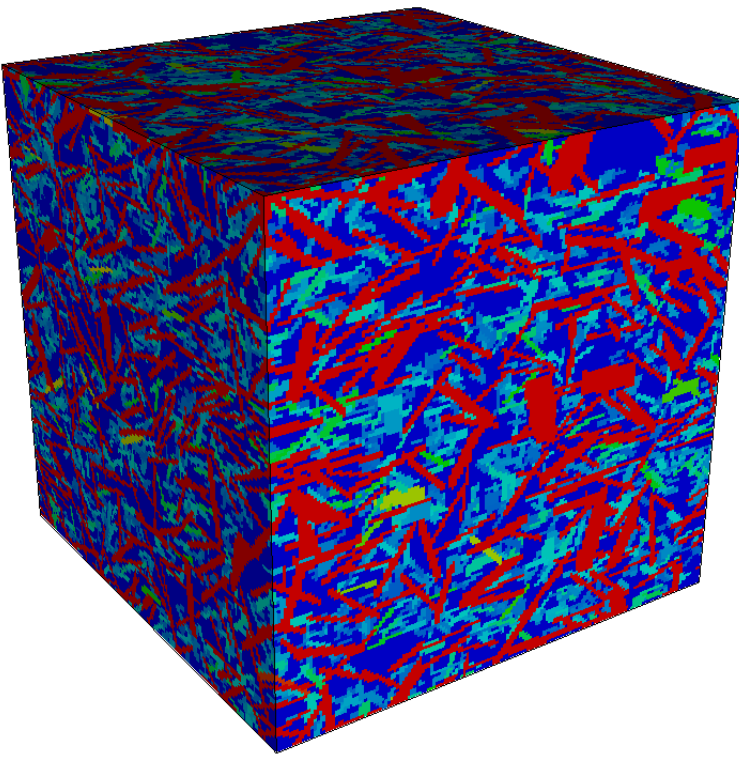


Mapping of DFN into a Continuum

Var: Permeability (m²)

1.910e-17
1.433e-17
9.554e-18
4.782e-18
1.000e-20
Max: 1.910e-17
Min: 1.000e-20

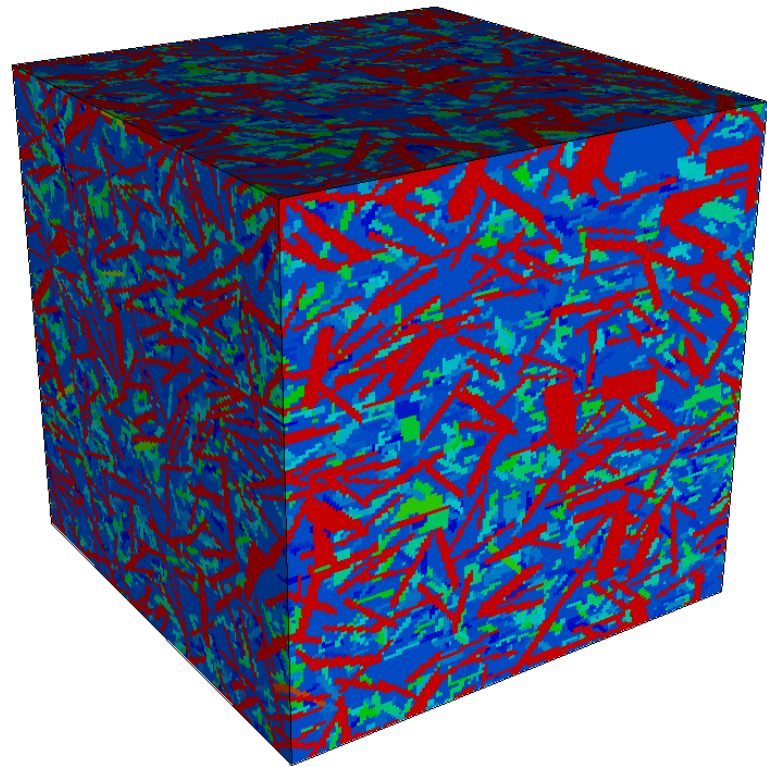
Permeability Field



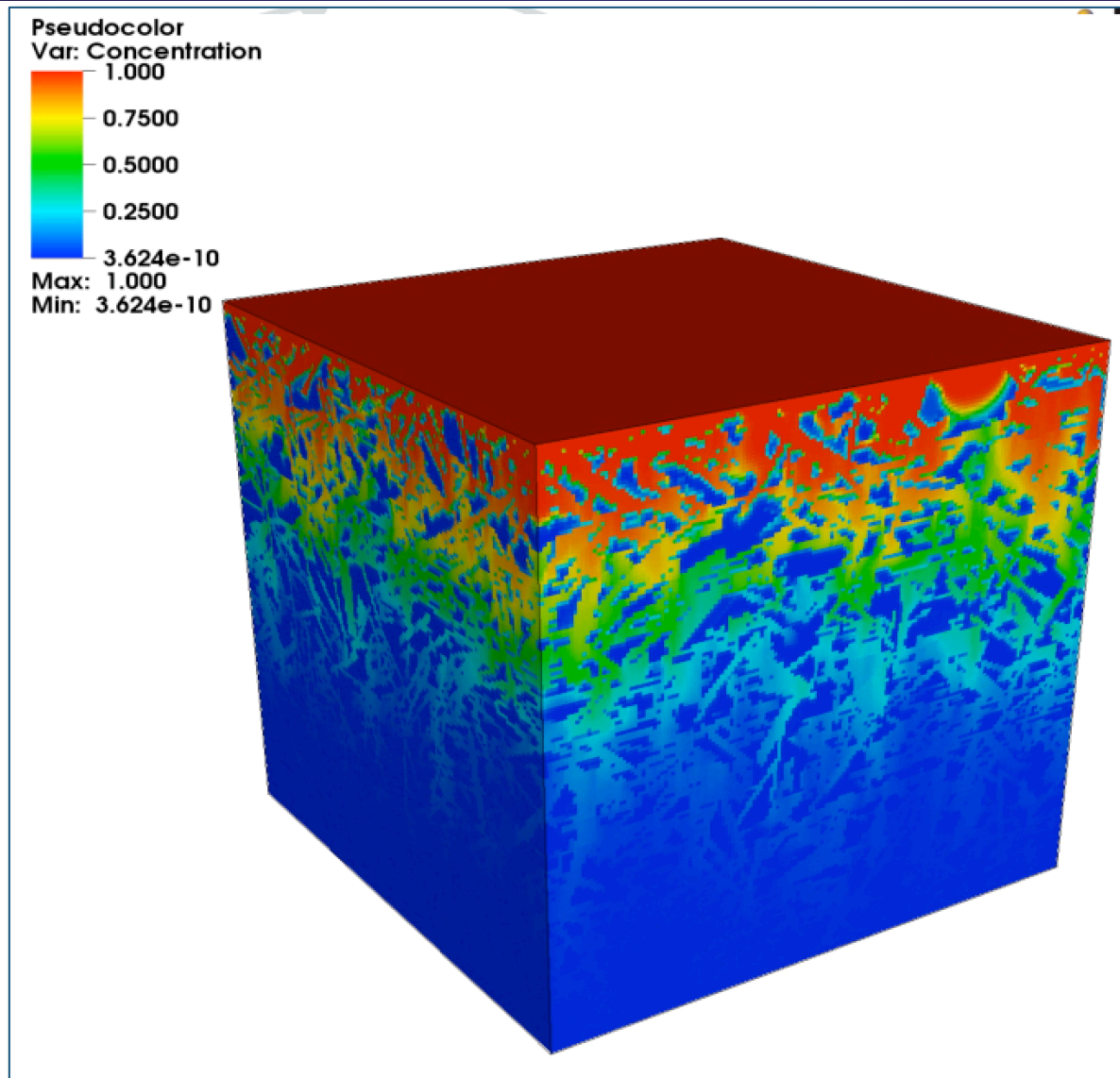
Var: Porosity (%)

0.9008
0.7345
0.5681
0.4017
0.2353
Max: 0.9008
Min: 0.2353

Porosity Field



Flow simulations, PFLOTRAN



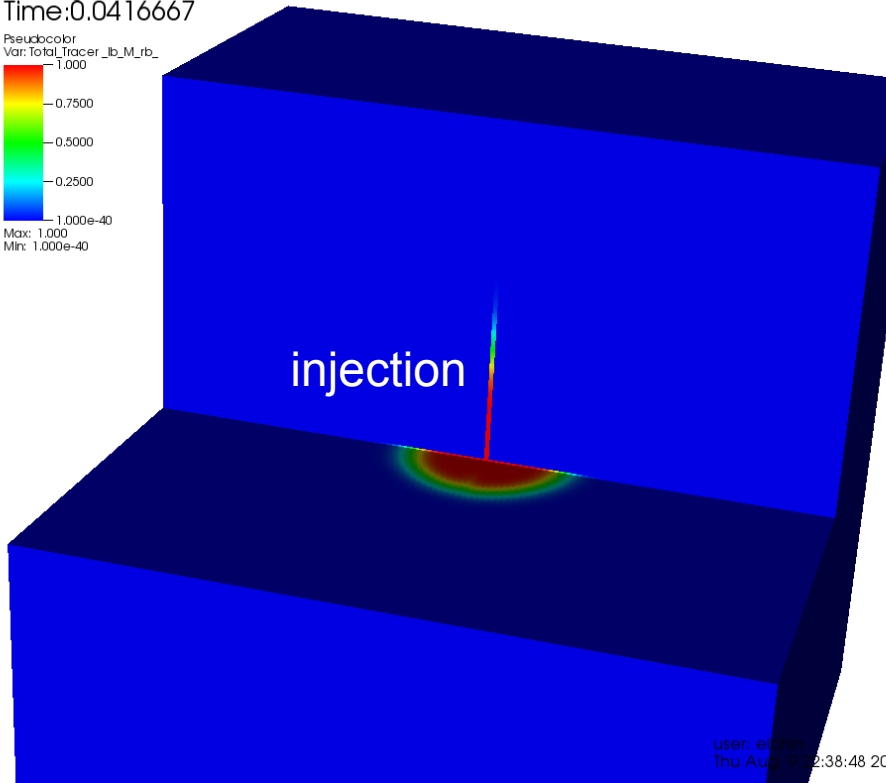
Discrete Fracture Network (DFN) Generation using synthetic data

- We model injection and production well, 10 m from each other, and circular hydraulic fracture ($R=15\text{m}$), which center coincides with injection well.
- The synthetic data was used to model natural sparse fracture network
- The stimulated hydraulic fracture is surrounded by a layer of small fractures (the layer width is 3 m, 1.5 m above and 1.5 m below hydraulic fracture) representing microfractures.
- PFLOTTRAN multiphysics code is used to model flow and tracer movement from injection well to production through stimulated fracture and existing natural fractures.

Single fracture flow

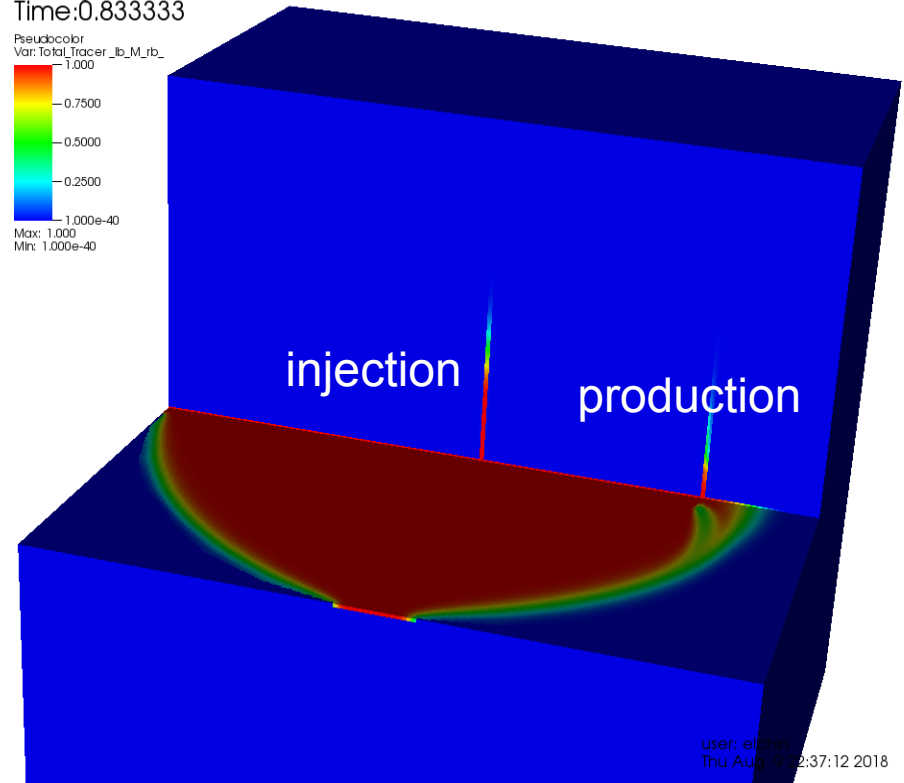
DB: sigmav-tracer-004.h5
Time:0.0416667

Pseudocolor
Var: Total_Tracer_lb_M_rb_
1.000
0.7500
0.5000
0.2500
1.000e-40
Max: 1.000
Min: 1.000e-40



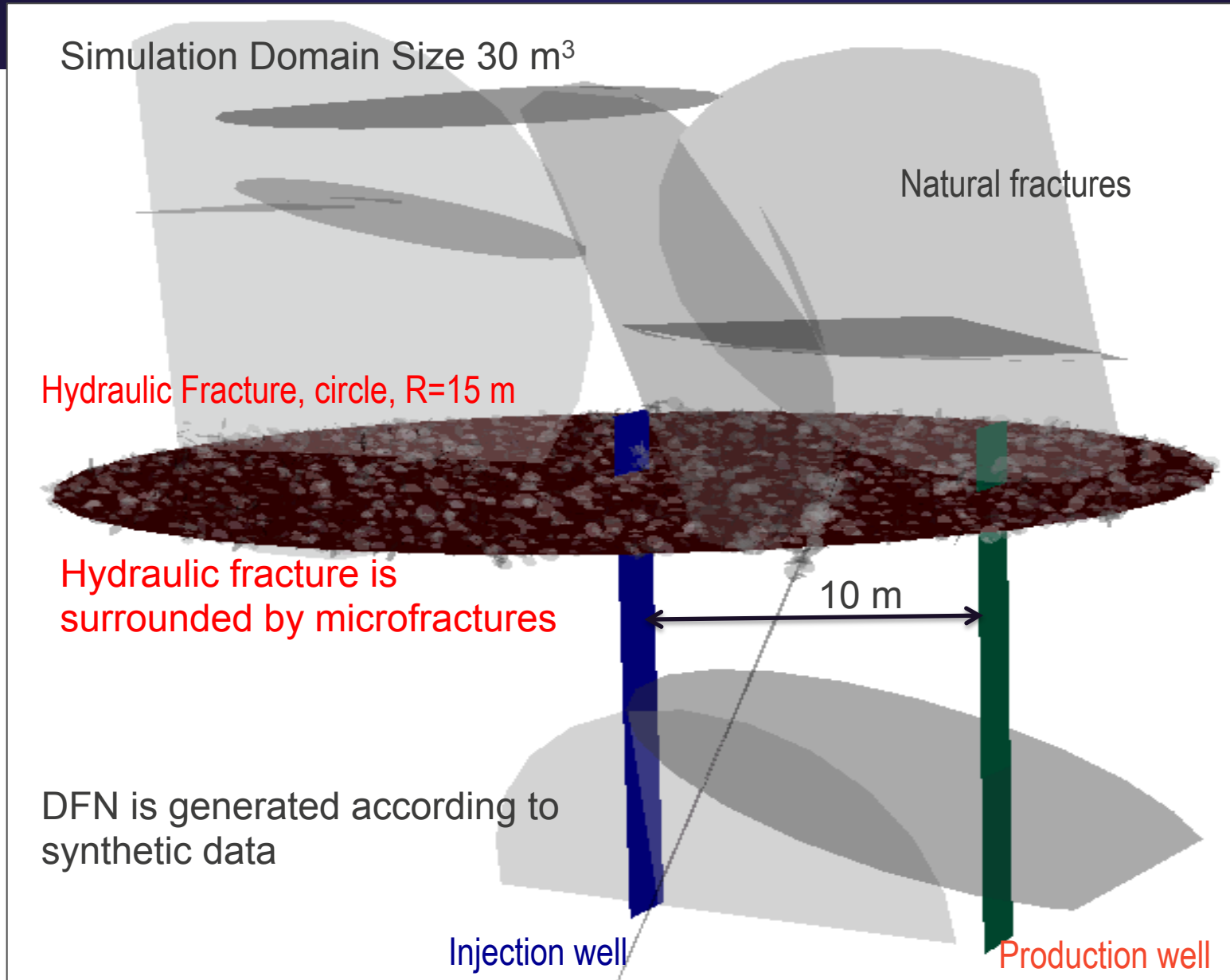
DB: sigmav-tracer-024.h5
Time:0.833333

Pseudocolor
Var: Total_Tracer_lb_M_rb_
1.000
0.7500
0.5000
0.2500
1.000e-40
Max: 1.000
Min: 1.000e-40



Tracer is injected through injection well, distributes through the fracture homogeneously, and moves into production well.

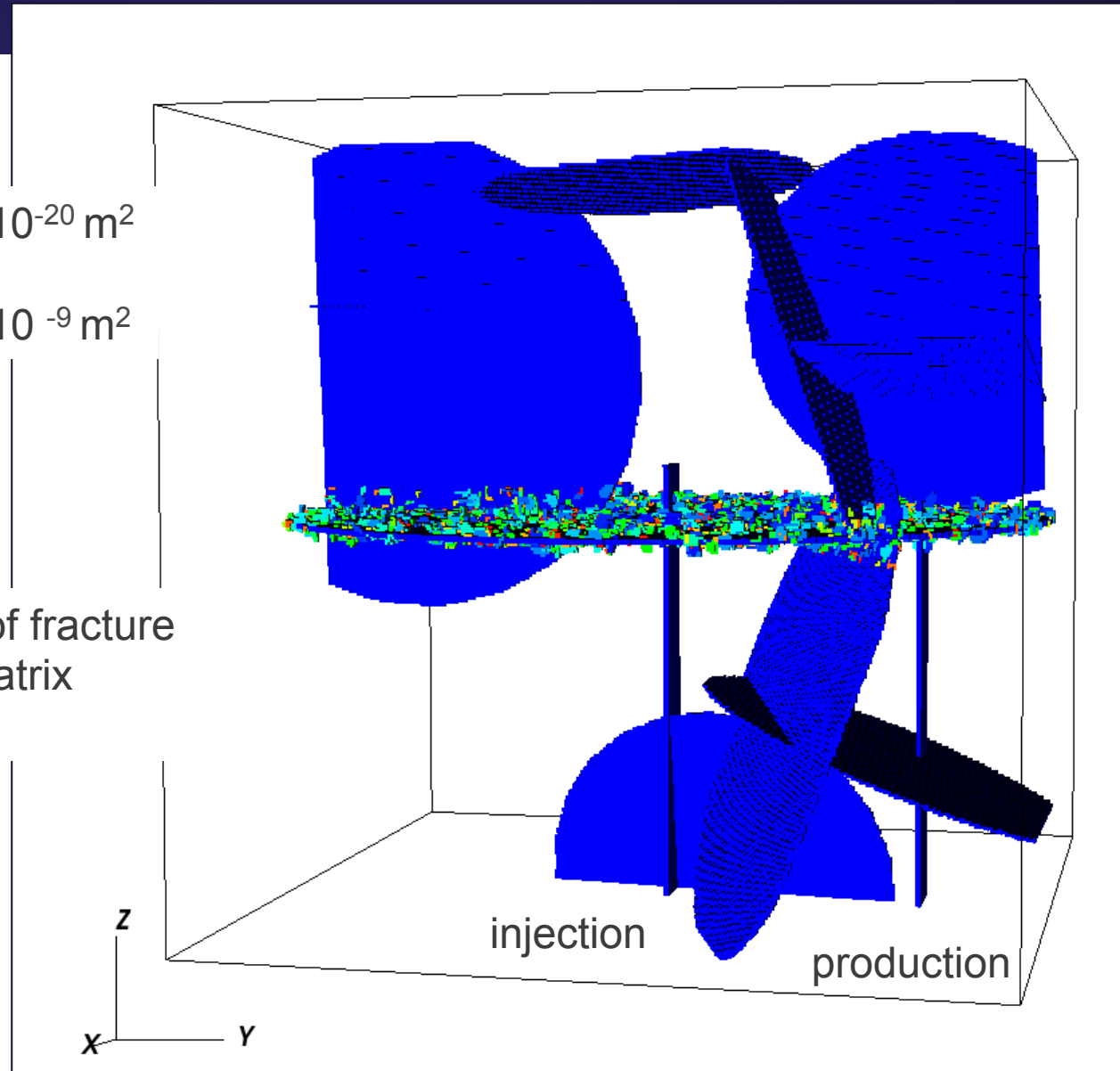
DFN realization



Generated DFN is mapped into continuum mesh

Permeability of matrix 10^{-20} m^2
Fractures
permeability $\sim 10^{-7} - 10^{-9} \text{ m}^2$

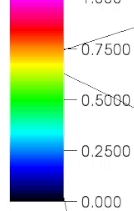
Here the hex mesh of fracture
cells is shown, no matrix
cells.



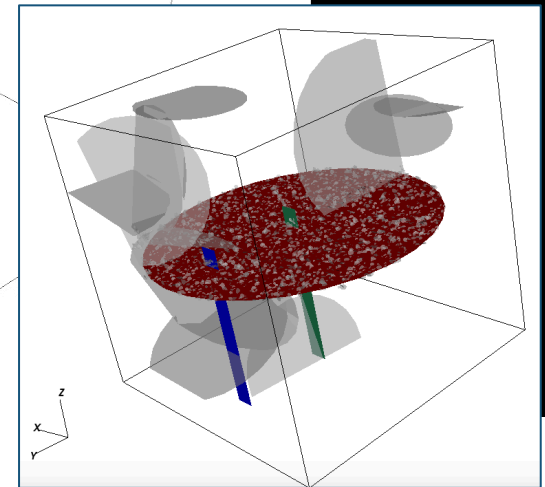
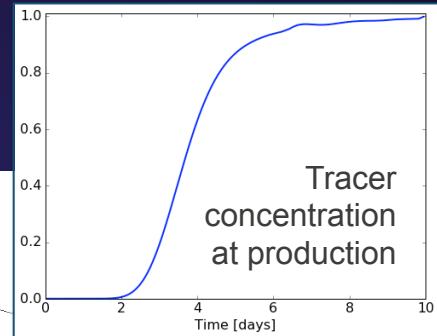
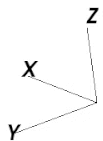
Tracer Simulation

DB: flow_10_l_min
Cycle: 0 Time:0

Pseudocolor
Var: Total_Tracer_lb_M_rb_



Max: 1.000e-40
Min: 1.000e-40



Moving Forward

Generate DFN
according to available
fracture characteristics

Apply flow and
transport input
parameters, used in the
experiments

Estimate natural
fracture network
connectivity

